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PAPER

The Role of Open-Source Software as a Technological Alternative for Blended Learning in LMS Systems

Florentino Méndez Gijón(✉), Victor Aguirre Hidalgo, Anahí Isabel Arellano Vega

Universidad de la Sierra Juárez, Oaxaca, Mexico

fmendez@unsij.edu.mx

ABSTRACT

Blended learning is a modality that combines the advantages of face-to-face teaching with those of e-learning. It requires the integration of information and communication technologies (ICT) in the teaching and learning process. For e-learning, it is necessary to configure a virtual learning environment (VLE). The virtualization task is carried out with the use of software that allows the digitalization of pedagogical interaction and learning management. This paper presents a literature review on the blended learning modality and the importance of software as a technological support. Subsequently, the role of open-source software (OSS) in technological development as a driver of innovation in the educational field is explored. This exploration was conducted by identifying the most widely used learning management systems (LMS) at the top universities listed in the 2024 QS World University Rankings, in the United States, Europe, and Mexico, and by describing the technological components of a VLE that has been fully and successfully implemented using OSS. The results of the literature search in the field of educational innovation reveal a scarce recognition of OSS in technological development and, therefore, in the processes of educational intervention. Therefore, works such as this one contributes to the recognition of software as a driver of technological progress.

KEYWORDS

blended learning, e-learning, open-source software (OSS), educational innovation, educational technology

1 INTRODUCTION

The development of technology, especially in information and communication technologies (ICT), has expanded the possibilities for innovation in education. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) recognizes the potential of ICT to help modernize the educational process.

Regarding the integration of ICT in teaching and learning processes, research has also revealed that they offer several advantages and benefits to teachers in the

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teaching process as well as in student learning, including ubiquitous learning and teaching, greater opportunities for interaction and synchronous and asynchronous communication, provision and reusability of content, monitoring of the training process, among others [1], [2], [3].

The blended learning modality is considered effective for the integration of ICT with web tools and the use of a virtual learning environment (VLE) in formal face-to-face educational contexts. This modality makes it possible to combine the best of face-to-face teaching with the possibilities offered by virtual teaching, since it makes it possible to improve certain pedagogical functions, such as synchronous and asynchronous communication, interaction, and critical thinking [4], [5], [6], [7].

For the deployment of a VLE, various technological elements are required, including software to manage techno-pedagogical content, user administration, report generation, and communication. This software is typically developed and distributed under a license that can be either proprietary or open-source. However, in this study, we primarily focus on reviewing open-source software (OSS) [8], [9].

2 THEORETICAL BACKGROUND

The concept of blended learning, as defined by [10], is understood from three distinct perspectives, each addressing the question of what is being blended.

1. Combination of teaching modalities.
2. Combination of teaching methods.
3. Combination of online and face-to-face teaching.

The last approach is taken, as it is closer to the historical emergence of the concept of blended learning, which deals with the combination of face-to-face teaching with computer-mediated teaching. This definition highlights the union of two historically separate teaching and learning models: face-to-face teaching and distributed learning systems, as well as the emphasis on the central role of computer systems in blended learning.

In considering the integration of face-to-face and computer-mediated teaching, some authors have proposed defining the concept of blended learning according to the proportion of time allocated to each modality. For instance, in [11] and [12], it is posited that a portion of the time originally allocated to face-to-face teaching is replaced by online activities. Similarly, in [13], four categories of blended learning are delineated. The four categories of blended learning are as follows: (1) traditional, with 0% online activities; (2) web-supported, between 1% and 29% online; (3) blended, between 30% and 79% online; and (4) online, with 80% or more online activities.

Additionally, in [14], the quality variable is incorporated into the concept of blended learning and is defined as the reflective integration of online learning experiences with face-to-face learning experiences. This definition encompasses course formats in which online activities and face-to-face teaching activities are integrated in a planned and pedagogically valuable manner.

In summary, blended learning is an educational modality that combines the strengths of e-learning with face-to-face teaching, with the teacher present, collaboration, and reflective oral and written communication is encouraged, which strengthens reflection and critical discourse; in addition, the benefits of synchronous verbal communication of face-to-face teaching strengthen community, achieving a guided and collaborative learning experience [15], [16].

E-learning takes advantage of academic resources in digital format, and academic interaction is carried out through digital channels. For the processing and management of these information resources, as well as for the digitization process, a variety of software adapted for implementation in a VLE. These resources and forms are combined with face-to-face teaching to configure the blended learning modality, as shown in Figure 1.

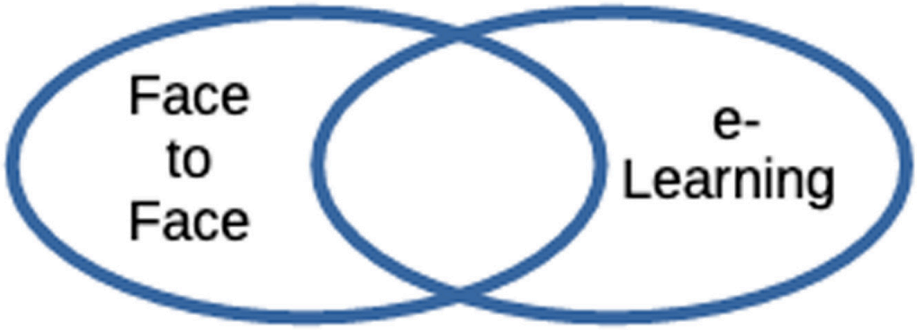

Fig. 1. Blended learning model

From this perspective, and for this paper, the e-learning part should consist of a VLE in its technological component. The VLE is used to create and manage virtual training activities, mostly asynchronous, and consists of elements that allow the management of users, courses, communication services, and academic interaction [17], [18].

The software that is part of a VLE can be categorized as a server, virtual classroom platform, and authoring tools. The server is an operating system that handles the resources needed to run the software applications. For its part, the virtual classroom platform consists of a web system that includes both a backend, consisting mainly of the web server and the database manager, and a frontend that houses the tools necessary to carry out the teaching and learning process [19]. The authoring tools are applications used to develop didactic content packaged in learning objects, such as the SCORM format and others.

In this context of the digitalization of teaching and learning, technological requirements have become of fundamental importance. In this sense, the distribution characteristics of OSS become highly relevant. This is partly due to its freedom of use and distribution, which allows it to be adapted to the specific needs of different university environments [20].

The concept of software is defined as a complex product built by programmers and executed on a computer to solve problems, defined in its design and development. There is software for different purposes, among them, those focused on education [21]; from a philosophical and economic point of view, software can be classified into copyleft or OSS-licensed software and copyrighted or proprietary software.

Copyright software, in general, has high costs and entails restrictions on its use and distribution. Among its other characteristics is the impossibility of generating copies for distribution, a limited number of computers and users, and distribution without the source code, which makes it difficult to meet certain user needs and limits its study to the detriment of learning [22].

Open-source software is, in many ways, the opposite of copyright software since it is distributed under a copyleft license. Copyleft is a type of license that grants the user unlimited freedoms, including the freedom to run, adapt, share, and improve the software. This is possible because the user has access to the source code [23].

It is important to note that none of these four freedoms addresses the issue of free software, i.e., OSS does not have freedom of cost as a mandatory requirement,

although in most cases this is an inherent characteristic of this type of software; however, the cost of the software is not a limiting factor for the concept of freedom of knowledge.

The OSS also finds ideological support in Linus' Law, which basically addresses the three motivations of human beings to build things: survival, social life, and entertainment. In his theory, he concludes that hackers (programmers) are motivated by entertainment and aim to make interesting things in the community, to share their creations so that they have a social benefit, without being interested in the economic issue, or at least without the economic issue being part of their priorities [24].

Open-source software features have been beneficial in reducing the digital divide and promoting technological development. They also have had a positive impact on education by providing free alternatives to proprietary software, which has high licensing costs and limits customization. However, OSS faces direct competition from large multi-billion-dollar corporations that exert increasing control over the revenues of large universities [25].

In education, and especially in the advancement of e-learning, OSS plays a key role in the adoption of ICT. Often, the positive contribution of OSS can go unnoticed, although this type of software acts as the foundation for a variety of technological developments that drive e-learning, including artificial intelligence, machine learning, and the Internet of Things [26].

Similarly, the Internet as a communication network and information exchange services, which are fundamental to the operation of e-learning, are based on OSS solutions. For example, the GNU/Linux operating system; web server applications such as Apache and Nginx; and database management systems such as MariaDB and PostgreSQL. In addition, programming languages and development frameworks are largely distributed using OSS principles [27].

Therefore, it is important to recognize the importance of OSS in the technological development of ICT, which supports some of the processes of educational innovation.

3 METHODOLOGY

The methodology followed was of the exploratory type, with a bibliographic and hemerographic review of blended learning and technological support. In the research process, a VLE built entirely with OSS was also deployed and used to support an e-learning context.

In the exploratory phase, a search was conducted for the most widely used LMS on the websites of the top 10 universities from the 2024 QS World University Rankings, both globally and in Mexico. This was achieved using the web scraping technique implemented in Python, utilizing the BeautifulSoup and Scrapy libraries. Keywords included 'Virtual Classroom' and 'LMS,' along with the names of the top 10 LMS brands based on user numbers [28]. Subsequently, universities were categorized by LMS usage, and the percentage of use was calculated in relation to the total number of institutions analyzed.

Among all LMS systems, the most widely used open-source option was selected, and their support website was examined to identify software requirements, ensuring that the necessary software was available as open-source. The following research questions were addressed:

RQ1: What are the most widely used LMS in universities across Europe, the United States, and Mexico?

RQ2: Are there OSS resources available to support OSS-type learning management systems?
RQ3: Is it feasible to deploy a fully OSS-based VLE that meets the needs of a higher education institution?

4 RESULTS

From a cost-benefit perspective, Table 1 presents the most widely used LMS at the top universities in the 2024 QS World University Rankings across the United States, Europe, and Mexico, highlighting some of their technical characteristics and types of licenses. In the literature review, there were insufficient sources addressing the technological properties of OSS in the deployment and operation of a VLE. Therefore, the implementation of the platform described in Table 2 served to validate the benefits of OSS in configuring a blended learning modality.

Table 1. Most widely used LMS at major universities in the United States, Europe, and Mexico

LMS	Times Used	Type of License	Software Background
Moodle	9	Completely Open-Source	Database: PostgreSQL or MySQL Operating System: Linux or Windows Web Server: Apache or Nginx
Canvas	5	Open-Source with limitations	Database: MySQL, PostgreSQL, MariaDB, MS SQL Server, or Oracle Operating System: Linux or Windows Web Server: Apache, Nginx, or IIS
Blackboard	4	Business License	Database: Oracle or Microsoft SQL Server Operating System: Linux or Windows Web Sever: Apache or IIS
Edx	1	Open-Source	Database: MySQL or MongoDB Operating System: Linux Web Server: Nginx y Gunicorn

Table 1 shows that Moodle is the most widely used LMS globally and among Mexican universities. It is a fully open-source and highly customizable LMS, making it an economical and flexible option. Furthermore, Moodle enables the deployment of an OSS-based VLE, as there are OSS options for server software, operating and support software, as well as application software and programming languages. This finding is consistent with [29].

Canvas is a predominant option among American institutions due to its seamless integration with commercial cloud services, which simplifies deployment. Blackboard, on the other hand, is favored by institutions seeking commercial solutions with robust support, although it is more costly and less flexible than Moodle. In summary, Moodle stands out as an OSS-based LMS solution and the most affordable option, particularly for public universities and institutions with technical staff capable of handling its deployment and maintenance.

Using the information obtained, a VLE was deployed with OSS. The components of this VLE are shown in Figure 2, highlighting how the software's properties can replicate the physical and social spaces of an educational institution.

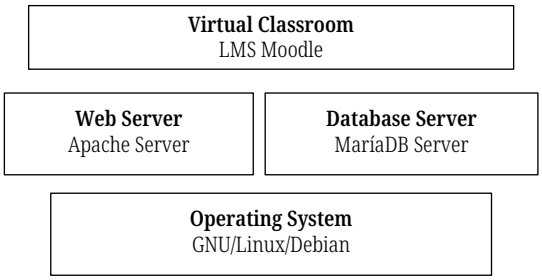

Fig. 2. VLE software elements

Some of the protocols that support academic communication in a VLE are listed below. The hypertext transfer protocol (HTTP) is implemented on a website with the logical infrastructure to enable the interaction of the teaching and learning process. This logical infrastructure requires an operating system, an application web server, the database manager, and the LMS software.

Existing OSS options are used to meet these requirements. In terms of the operating system, the Debian GNU/Linux distribution has been used, it is completely free to use and is maintained and supported by a global organization of volunteers. The operating system manages the physical resources of the infrastructure and provides an interface to connect the VLE to the outside world, abstracting the complexity of data communication.

The Apache web server was used as the application server. Developed by the Apache Software Foundation and released under the permissive Apache License, it provides full access to its source code. Apache supports web applications built with PHP; an open-source language also used in developing Moodle LMS.

The database management system is MariaDB Server, distributed with the open-source guarantee; it is fast, scalable, and robust and used in relational database scenarios. This software stores and organizes academic information in the form of tables, indexes, and records to access it in an efficient way.

Finally, the fundamental piece of e-learning is the computer application that provides the functionality to the virtual classroom, the LMS software, which for its operation is implemented in the logical infrastructure deployed with the previously described software.

For this study, Moodle LMS was chosen because it is one of the most widely used OSS solutions in universities. It also supports an educational model that allows users to create and participate in shared online learning experiences. Additionally, according to its official website, this LMS is backed by a community of users, administrators, companies, and development experts who contribute to its support and ongoing innovation.

This LMS is secure and reliable because thousands of developers are involved in its creation, and because it is OSS, which guarantees the supervision of the code by the community. In addition, with the freedom of distribution, you can use it anywhere, which guarantees the control of the privacy of your data.

Also, Moodle, with its thousands of plugins of different categories, can be customized to adapt to institutional needs, significantly increasing its functionality. In the implementation of this study, plugins without license fees or restrictions were used to build a customized virtual classroom in alignment with the university context where the research was carried out.

A critical component of an e-learning system is the digital instructional content that can be presented in the form of text, audio, or video. This content includes learning activities, formative and summative assessments, and other elements.

In addition, a critical component of an e-learning system is the digital instructional content that can be presented in the form of text, audio, or video. This content includes learning activities, formative and summative assessments, and other elements. It is developed using authoring tools. In this context, OSS offers many possibilities. One of the applications tested was Exe Learning, which allows the generation of techno-educational content in HTML, ePub3, and SCORM formats, all compatible with Moodle learning management system.

Table 2 shows a summary of the software described in the previous paragraphs, with which it was possible to configure a VLE to implement e-learning as part of the blended learning modality, implemented in the institution where the research was carried out.

Table 2. OSS applications for e-learning systems

Application	Organization Supporting It	Usage	Pedagogical Approach
GNU/Linux/ Debian	Debian	Operating System	Not applicable
MariaDB Server	MariaDB Foundation	Database manager, where the information of the e-learning environment is stored in a structured way	Not applicable
Apache HTTP Server	Apache Software Foundation (ASF)	Web server that manages the communication process for the exchange of information for the teaching and learning process	Not applicable
LMS Moodle	Moodle Corporation	The course management system through which the VLE is implemented	Constructivist Connectivism
Exe-Learning	Community and Institutions	Authoring tool	Diverse

Table 2 shows a predominant use of OSS for deploying the VLE as a fundamental component in the operation of e-learning. This implementation supported an educational intervention aimed at innovating teaching practices and promoting the development of digital competencies.

Also in Table 2, the pedagogical approaches of the LMS Moodle and the Exe-Learning content generator can be observed. From a constructivist and connectivism perspective, these tools align with the idea that individuals actively build new knowledge through their interactions with their surroundings. They emphasize that everyone has the potential to be both a teacher and a learner; in a genuinely collaborative setting, these dual roles are naturally embraced [30].

5 DISCUSSIONS

The literature review found little dissemination of the use of OSS in educational innovation processes, especially in the deployment of VLE, despite being the source of much of the technological development, which has driven positive changes in the teaching and learning process. An example of this development is the Internet, where OSS is present in all information processing and administration processes, including programming languages, GNU/Linux operating systems, web servers, database management systems, and much more.

One of the most widespread uses is related to open access and copyleft licenses. These concepts and license types have their roots in OSS philosophy. This trend has allowed the creation and deployment of numerous sources of educational resources, facilitating innovation in education, thanks to their free access. Among these resources are massive open online courses (MOOCs). However, many of these courses do not allow modification of their content.

Open-source software has also been used in the development of artificial intelligence (AI), under the term open-source intelligence (OSINT), which is defined as the search, collection, processing, analysis, production, classification, and use of information from open sources. AI is a promising field that supports technological innovation and, therefore, is favorable for educational innovation.

It is evident, then, that a large part of technological development has started with OSS. Therefore, this type of software is fundamental to the functioning of ICT in education. Recognizing its characteristics and how it supports educational innovation processes can encourage the development of actions that favor the thoughtful adoption of ICT in education.

6 CONCLUSIONS

In the literature review on comparative performance studies of different open-source LMS platforms, as well as in the findings obtained through the web scraping technique, Moodle emerges as the most widely used platform. Consequently, it can be inferred that Moodle is the optimal choice for deploying a VLE when selecting an open-source learning management system.

The review found that OSS fulfills an important social function, and that due to its ideological and philosophical roots, it is not only a viable technological option but also advisable to be used as a support for a VLE, as well as for the development of learning objects. These technological components are crucial to the implementation of the blended learning model.

During the research and analysis of multiple applications, different types of software were found with licenses that guarantee the freedom of OSS. These licenses allow the implementation of a VLE to support the modality blended learning, ensuring that the teaching and learning process can be supported by information and communication technologies.

As a result, this study contributes to the body of knowledge on educational innovation that takes advantage of OSS as a fundamental part of technological development.

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8 AUTHORS

Florentino Méndez Gijón holds a bachelor's degree in electronic engineering, a master's in information technology engineering, and a PhD in Innovation in Educational Technology. He has nearly ten years of professional experience as head of the ICT department in both public and private institutions. Since 2010, he has served as a professor-researcher in the bachelor's program in Computer Science at Universidad de la Sierra Juárez, México. He has been a certified instructor at Cisco Systems Netacad Academy; he was honored with the "5 Years of Active Participation and Service in Cisco Networking Academy" award. In 2022, he was recognized as a candidate for the National System of Researchers (SNI) by CONAHCYT, México. Since 2014, he has held the Recognition of Professor with a Desirable Profile awarded by PRODEP-SEP México (E-mail: fmendez@unsij.edu.mx).

Victor Aguirre Hidalgo, a Biologist graduated from Universidad Nacional Autónoma de Mexico (UNAM) in 1997. Earned a master's degree in Ecology and Environmental Sciences from UNAM in 2002 and a PhD in Biological Sciences from the University of Plymouth, UK, in 2008. Completed a postdoctoral fellowship in Biology

at the Institute of Biology in 2009. Currently serves as a Full-Time Professor-Researcher (Titular A) at the Universidad de la Sierra Juárez. Recognized as a member of the National System of Researchers (SNI-I) by CONACYT as of 2025.

Anahí Isabel Arellano Vega, PhD in Innovation in Educational Technology from the Universidad Autónoma de Querétaro (UAQ), master's in development and school learning from the UAQ, and specialist in Information Technologies for Learning from the Interdisciplinary Center for Research and Teaching in Technical Education (CIIDET). I hold a bachelor's degree in educational psychology from UAQ. Member of the National System of Researchers (SNI) at Candidate Level. Associate Member of the Mexican Council for Educational Research (COMIE). Member of the Interinstitutional Research Group TICCAD in University Teaching Practice. Coordinator of the Collegiate Group in Training Psychological Processes and Emerging Technologies. Serves as a teacher-researcher at the Faculty of Psychology and Education of the UAQ.